

# Airplane and Helicopter Spraying with DDT for Spruce Budworm Control<sup>1</sup>

IN 1948 tests were conducted with DDT applied by airplane and helicopter for control of the spruce budworm (*Archips fumiferana* Clem.). This work was done near Heppner, Oregon, by the U. S. Bureau of Entomology and Plant Quarantine, in cooperation with the Oregon State Board of Forestry, the U. S. Forest Service, and the Kinzua Pine Mills Company.

Approximately 4,200 acres of infested forest located in the mixed Douglas-fir and grand fir stands of eastern Oregon, on lands of the Umatilla National Forest and the Kinzua Pine Mills Company, were sprayed under contract with a commercial concern between June 22 and July 2. The total area of infestation in the mixed-forest type of eastern Oregon and Washington is estimated at nearly 1½ million acres. In addition, 100,000 acres of high quality Douglas-fir in western Oregon are also infested. The outbreak is by far the most extensive on record for this destructive insect in these two states. The degree of defoliation varies throughout the region and trees are already dying in limited areas. All indications point toward further spread of the infestation, and a heavy loss of timber.

Between 1945 and 1947, the Bureau of Entomology and Plant Quarantine and cooperating agencies conducted experiments in New York and eastern Canada with DDT aerial sprays to control the spruce budworm. Studies of spray formulations, dosages, and equipment during this period have revealed a number of things.

1. Oil solutions appear to be preferable in several respects to either suspensions or emulsions of DDT against the budworm. Emulsions may be most hazardous to fish. Suspensions in the concentrations required for airplane spraying must be mixed just before they are used, and often cause clogging of the distributing apparatus.

2. In oil solutions a dosage of 1 pound of DDT in 1 gallon of fuel oil per acre, when applied from the air with suitable spraying equip-

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ment, is sufficient to reduce the budworm population materially.

3. Weather factors greatly influence the distribution of the spray and impose serious limitations on aerial operations. Concurrent studies of budworm development in relation to spray applications have shown that the insect is most vulnerable during the two- to three-week period when the larvae are actively feeding in the elongating shoots. The habits of the insect make timing of spray applications with respect to the development of both larvae and foliage extremely critical. The tiny budworm larvae, upon emergence from hibernation in the spring, enter and mine the needles of the previous year's growth. As soon as the buds swell the larvae leave the needles and enter the expanding buds. While in the unopened buds the larvae are effectively protected from DDT sprays. It is not until the new shoots have expanded at least ½ inch that the larvae move about enough to expose themselves to the spray.

These studies were generally small-scale experiments with light to moderate spruce budworm populations. Proof was needed of the effectiveness of DDT sprays against heavy populations, with practical spraying procedures that could be used on an actual control operation. An excellent opportunity for the additional tests required was afforded by the widespread spruce budworm epidemic in Oregon in 1948.

## The Experimental Area

For the 1948 tests an experimental area of 160,000 acres was chosen where spruce budworm populations were generally heavy. The greater part of this area is a timbered plateau, 4,000 to 4,500 feet in elevation, lying north of the breaks of the John Day River and extending from Swale Creek on the east to the Spray-Heppner highway on the west. The forest on this plateau is a two-storied stand of mixed fir-ponderosa pine type. Douglas-fir and grand fir are the species that

are susceptible to spruce budworm attack. Together they comprise about 20 percent of the merchantable stand and a considerably higher percent of the understory. In general, the experimental area is typical of much of the forested area in the Blue Mountains of Oregon.

Within the experimental area twelve plots of 350 acres each were selected for spraying, and two additional plots of similar characteristics, but sufficiently removed from the spray plots to avoid contamination due to drifting spray, were reserved as check plots. All the plots were situated within a 5-mile radius of Opal Butte. The spray plots were generally rectangular and were located so as to conform to fir-type areas in which budworm infestation was most severe.

The plot corners were marked with large painted wooden or rock crosses on the ground (where suitable openings occurred), with painted trees, or with white cloth streamers suspended from corner trees. An ingenious method for marking these corner trees, most of which were 100 to 140 feet high, was developed on the project by W. J. Buckhorn. It consisted briefly of shooting a line with a line-throwing shoulder gun over the tree to be marked. The line was then used to haul up a cloth streamer or a paint bomb. The paint bomb, consisting of a quart of aluminum paint in a fiber container in which was inserted a detonator and one quarter of a stick of dynamite, was electrically detonated from the ground. The explosive force effectively scattered the paint through the upper crown so that the tree was visible for some distance from the air, but it did not cause any apparent injury to the tree.

### **Spray Materials, Equipment, and Procedures**

The insecticide was an oil solution of DDT mixed at the rate of 1 pound of technical grade DDT in 1.2 quarts of a hydrocarbon auxiliary solvent diluted to 1 gallon with fuel oil. The spray was mixed in the field with a mobile tank-mixing unit. The dosages tested are listed in Table 2.

Both a biplane (Travelaire 4000) and a helicopter (Bell 47 B-3) were used to apply the spray. The spraying equipment on each aircraft was similar and consisted essentially of a spray tank from which the insecticide was distributed by a pump to a boom fitted with nozzles. On the biplane the spray tank was installed in the front

cockpit and the boom was suspended along the full length of the lower wing. On the helicopter the spray tank was divided into two units, each fitted to the sides of the ship behind the pilot's compartment. The spray boom, mounted so as to extend outward from each side of the ship, was 22 feet long. Positive pressure on the spraying system was maintained by a centrifugal pump, wind-driven on the biplane, and motor-driven on the helicopter. Both ships were fitted with commercial spray nozzles producing a hollow cone spray pattern; the nozzles on the biplane had a  $\frac{1}{8}$ -inch orifice and on the helicopter, a  $\frac{1}{16}$ -inch orifice. When the required number of nozzles was used, the biplane was calibrated to deliver 1 gallon of spray per acre over a 132-foot swath at a normal operating speed of 80 miles per hour. The helicopter was likewise calibrated to deliver 1 gallon per acre over a 70-foot swath at an operating speed of 50 miles per hour.

Because of the elevation at which this operation was carried on, the spray-carrying capacity of the helicopter was limited to about 35 gallons. In contrast, the biplane carried regularly 75 gallons of insecticide. The helicopter was operated from the Kinzua Pine Mills Company's main logging road (elevation 4,350 feet) within the experimental area. A short, straight stretch of this road provided the necessary runway required for successful ascent by the helicopter with a full load. The time saved in operating the helicopter from this roadway, close to the plots, just about compensated for its limited carrying capacity. The airplane was operated from a temporary landing strip (elevation 3,590 feet) in a wheatfield about 9 miles north of the plots.

With but one exception spray flights were restricted to early morning hours, when calm air or low-wind velocities prevailed. Spraying was suspended when the wind velocity reached 6 miles per hour. However, it was found that excessive turbulence rather than high-wind velocity usually limited spraying. One thunderstorm, with light precipitation, occurred during the spraying period, but in all tests the foliage was dry or but slightly damp at the time of treatment.

The direction and alignment of spray runs were governed largely by topography and were for the most part left to the discretion of the pilot. Marking of individual swaths was im-

practical, owing to the dense undergrowth and to the height of the overstory. The procedure used in applying the various treatments was about as follows: Airplane applications of the 1-pound dosage were made in parallel swaths approximately 132 feet apart, and the 2-pound dosages, approximately 66 feet apart. With the helicopter, a  $\frac{1}{2}$ -pound dosage was applied to one plot in parallel swaths approximately 140 feet wide. Two plots were treated with a 1-pound dosage by applying half the dosage on parallel swaths 140 feet wide in one direction, and the balance on comparable swaths at right angles. The remaining treatment with the helicopter (a 1-pound dosage) was applied in parallel swaths 70 feet wide.

Spray flights were generally made 25 to 50 feet above the overstory trees. Aerial photographs and a type map based on the photographs were used to advantage in laying out the plots and in orienting the air and ground crews. Radio communication between the landing sites and the spraying areas, by means of light-weight radios provided by the Oregon State Board of Forestry, proved of inestimable value in coordinating activities during spraying.

### Timing of Spray Application

Since timing of spray applications against the spruce budworm is so critical, the development of larvae and foliage was checked daily before and during spraying to insure that the treatments were applied when the insect was most vulnerable. When spraying was begun, most of the shoots on Douglas-fir were about  $\frac{1}{2}$ -inch long, while the shoots on grand fir were from 1 to 3 inches long. The status of larval development on each plot at the time of spraying is shown in Table 1. These data also reflect the progressive development of the larvae during the period June 22 to July 2, when spraying operations were underway. Prepupal larvae began to appear on the latter date. It seems evident, therefore, that the insecticide was applied during the period of insect and foliage development when the budworm is most readily controlled by spraying.

### Measuring the Effects of the Spray

The effect of the spray was measured by sampling the larval fall from ten sample trees selected along a diagonal line across each plot. These lines ranged from 50 to almost 100 chains

in length, and the distance between sample trees ranged from 5 to 10 chains. Douglas-fir and grand fir were sampled in proportion to their occurrence in the stand. Individual trees ranged from about 6 to 14 inches in d.b.h. and from 40 to 75 feet in height. Most of them had long, full crowns, which were supporting a heavy larval population. From one to several days before spraying, a collecting tray made from a cloth strip 3 feet wide, and long enough to spread from one edge of the crown projection to the other, was placed beneath each sample tree. These trays were supported by stakes and weighted along the center to prevent the larvae from wriggling off. The same procedure was followed on the check plots. All trays were cleaned on the day prior to spraying, and no appreciable number of dead larvae were on the trays up to the time of spraying. After treatment the affected larvae were counted daily until most of the larval fall had ceased. This required about a week to ten days, depending somewhat on the effectiveness of the treatment. The trays on the check plots were also examined at regular intervals.

Several hundred larvae from sprayed and check plots were saved for observation. It was soon found that the larvae falling on the trays in the sprayed plots died within a day or two, while those from the check plots survived, except a small number that were parasitized.

Just prior to pupation, when larval drop had reached a minimum, all sample trees were felled on cloth strips. Surviving larval population and residual mortality were estimated from the results obtained by sampling the foliage and counting the larvae caught on the cloth. Total

TABLE 1.—LARVAL DEVELOPMENT OF SPRUCE BUDWORM ON PLOTS AT TIME OF SPRAYING. HEPPNER, OREGON. 1948

Method and date of spraying	Percent of larvae in each instar			
	Third	Fourth	Fifth	Sixth
Helicopter:				
June 22	2	57	41	0
23	2	56	42	0
	0	43	57	0
24, 25	2	43	55	0
25	2	40	57	1
26	1	34	61	4
Airplane:				
June 27, 28	1	25	71	3
28, 29	1	25	71	3
30	0	8	30	62
30, July 1	0	3	29	68
July 1	0	2	19	79
1, 2	0	2	8	90



tized larvae that escaped the spray, probably through failure to travel and feed. This is somewhat offset by the fact that control percentages in Table 2 have not been adjusted to include the effect of natural control factors. On none of the plots sprayed at the rate of 1 pound in 1 gallon or 2 pounds in 2 gallons per acre, with the possible exception of the plot sprayed in the evening, were there enough surviving larvae to re-infest the sprayed trees to any appreciable extent in 1949.

No spray burning was noted on any coniferous, hardwood, or herbaceous foliage with any of the dosages used on this project.

The contrast between trees on the sprayed and unsprayed areas was striking within three weeks after the spraying was completed. On the treated plots the trees, especially the Douglas-fir, were beginning to green up, with new growth covering the feeding scars and red foliage. The grand fir showed less immediate response. On untreated, infested areas, bare twigs and reddish foliage were increasingly evident, presenting a devastating scene. In many untreated areas the mortality of both Douglas-fir and grand fir is expected to be heavy this year.

It is believed that these experiments demonstrate conclusively that heavy spruce budworm infestations in Douglas-fir and grand fir can be controlled in the mixed fir-pine forests of eastern Oregon, if spray—at the rate of 1 pound of technical grade DDT in 1 gallon of fuel oil per acre—is applied during the quiet morning hours at a time when the spruce budworms are in the late larval stages. Furthermore the spray can be applied by airplane or helicopter, the plane

being cheaper. The helicopter has the advantage, within its operational ceiling, of being usable on areas where a lack of adequate airfield facilities is the limiting factor.

### Summary

In 1948 tests were conducted on airplane and helicopter spraying with DDT to control the spruce budworm (*Archips fumiferana* Clem.).

Approximately 4,200 acres of infested forest in twelve 350-acre plots located in the mixed Douglas-fir and grand fir stands of eastern Oregon on lands of the Umatilla National Forest and the Kinzua Pine Mills Company were sprayed.

Excellent control was obtained with both 1 pound of technical grade DDT in 1 gallon of fuel oil per acre, and 2 pounds of technical grade DDT in 2 gallons of fuel oil per acre; however, the former dosage produced results nearly as good as the latter. A dosage of  $\frac{1}{2}$  pound of technical grade DDT in  $\frac{1}{2}$  gallon of fuel oil per acre gave unsatisfactory control.

The spray was applied during the short period in budworm development when the larvae are most vulnerable to insecticidal attack, i. e., when they are actively feeding on the expanding foliage.

The ability of the helicopter to operate from an improvised landing area close to the plots compensated for its limited carrying capacity in comparison with the airplane.

The aircraft spraying equipment used in this study, the method of timing the spraying, and the system used in checking the effects of the treatments on budworm larvae are described.